October 14, 2016

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: **Oral *Ex Parte* presentation in RM-11681 "Petition [by Ligado Networks] for Rulemaking to Allocate the 1675-1680 MHz Band for Terrestrial Mobile Use"; IB Docket No. 12-340 "LightSquared Request to Modify Its ATC Authorization."; IB Docket No. 11-109, Regarding the Ligado Modification Applications.**

Dear Ms. Dortch:

On October 12, 2016, the following representatives of the meteorological and ground system technology communities met with Daudeline Meme, Legal Advisor, Wireless, International and Public Safety to Commissioner Mignon Clyburn:

- Mr. Robert T. Ryan[1], retired broadcast meteorologist and former president of the American Meteorological Society
- Dr. Jordan K. Gerth, Associate Researcher, Space Science and Engineering Center (SSEC), University of Wisconsin-Madison
- Mr. Brett H. Betsill, Radio Frequency Equipment Design Engineer and Ground Station Manufacturer, President, Microcom Design, Inc.
- Ms. Renée A. Leduc Clarke, Founder and Principal, Narayan Strategy, a weather and climate policy consulting firm

The primary purpose of this meeting was to present information on how real-time water and weather information received directly from the GOES satellite in 1675-1695 MHz is used by the hydrometeorological communities and to discuss concerns regarding proposals to share 1675-1680 MHz with strong terrestrial transmitters proposed by Ligado Networks.

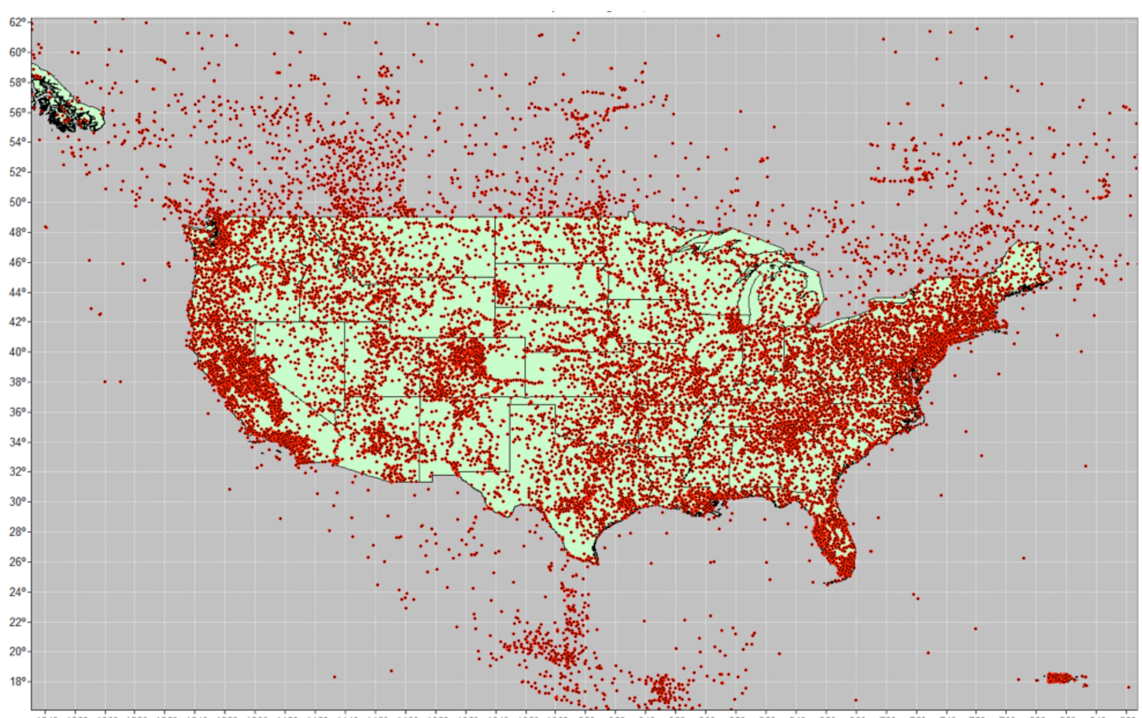
<u>Real-time Data Transmitted in 1675-1680 MHz is Critical to Public & Private Users</u>

[1] Mr. Ryan's comments in FCC Proceeding RM-11681, dated June 14, 2016 are located at https://ecfsapi.fcc.gov/file/60002218188.pdf

Meteorologists and hydrologists rely on real-time information transmitted through 1675-1680 MHz from NOAA's geostationary environmental satellites to produce forecasts that protect life and property.

One of the fundamental services of government is the protection of life and property. As we have seen during Hurricane Matthew, due to both winds and flooding, citizens in Florida, Georgia, North and South Carolina were directly impacted by this strong tropical cyclone, accompanied by significant rain and wind-driven storm surge. Floodwaters were still rising in North Carolina as we conducted this meeting after the principal cause – the hurricane - had weakened and moved out to sea.

The water levels and flow rates are measured by river, stream and coastal gages, which report their real-time data via the GOES (and the future GOES-R) using the Data Collection System (DCS). The GOES-R DCS will receive signals from over 27,000 collection platforms within this hemisphere and will directly relay them to users via the 1679-1680 MHz spectrum.



Data Collection Platforms (Hydrological Gages, Wildfire Weather Sensors, Weather Stations) Within the Continental US (Source: Microcom Design, Inc.)

It is crucial to hazard forecasting that the real-time information via the GOES direct broadcast system (and on the future GOES-R) always arrive at times where seconds matter. Receipt of this information must be assured, in response to major environmental hazards like hurricanes, floods and wildfires. The satellite broadcast, which is dependent on access to 1675-1680 MHz without interference, is a freestanding system that does not rely on commercial power[2] and connectivity that do fail in the most hazardous situations when the information is needed the most.

The users most in need of this direct, real-time data are technical users, such as meteorologists and hydrologists in the public sector (federal, state, local and tribal) and the private sector. Immediate access to these data by these diverse users helps to ensure the general public get accurate and actionable information via traditional means (such as the media and weather apps) to make decisions, especially in the midst of environmental hazards.

Information Via Direct Broadcast Protects the Safety of The Public and Supports the U.S. Economy Via Federal and non-Federal Efforts

The direct broadcast system is used by those federal, state, tribal and local governments as well as private sector users who know they must get information without delay about hazards that impact both the safety of the public and the U.S. economy.

If only a limited subset of Federal ground receiving sites, such as NOAA's, were protected, as proposed by Ligado, there are still many dozens of other private and public sector users of this information who require direct reception in the 1675-1680 MHz or 1675-1695 MHz band. A few examples were cited:

- The National Interagency Fire Center (NIFC), headquartered in Boise, Idaho utilizes the GOES DCS downlink and portable Remote Automated Weather Stations to monitor the ever changing weather conditions around wildfires to ensure the safety of firefighting personnel on or near the fire line, where seconds matter. While NIFC's primary focus is wildland fire suppression, their "equipment and personnel have been utilized on hurricanes, floods, earthquakes, volcanic eruptions, oil spills, and other man-made and natural disasters where federal assistance is required."[3]

- The U.S. Army Corps of Engineers receives GOES data at each of their 26 district offices in support of maritime navigation on inland waterways and the operation of locks and dams.

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[2] Earth stations can be operated on generators or backup power as the only terrestrial interface point for a GOES or GOES-R based relay, (i.e., the only thing between the user and the data is the GOES satellite), whereas a terrestrial system has multiple points that could fail under hazardous conditions, including the "last-mile" connectivity.

[3] Per the website of the NIFC, https://www.nifc.gov/

- South Florida Water Management District (SFWMD) – which receives DCS data directly to manage water usage and flooding in their part of the state via the Central and Southern Florida Project. That system of canals and natural waterways connects to community drainage districts and hundreds of smaller neighborhood systems to effectively manage floodwaters during heavy precipitation events. (Their water managers have been very busy managing effects from Hurricane Matthew, monitoring conditions and making adjustments to the system around the clock. Direct reception of data without delay from the future GOES-R in 1675-1680 MHz will make that possible.)

- The Florida Department of Transportation[4] (FDOT) directly transmits wind speed data from bridges along the Florida coast via GOES into state-owned and operated DCS receivers so that timely bridge closure decisions may be made in severe environmental conditions such as hurricane force winds. Bridges from islands and across causeways remain open as long as officials feel that conditions are safe for evacuation. FDOT has invested in a primary and a backup direct reception station to acquire the wind speed on bridges in and around Jacksonville, where wind gusts monitored via 1679-1680 MHz were recorded at 100 miles per hour during Hurricane Matthew. And FDOT's next expansion will provide monitoring and real-time wind data for the bridges all along the roadway to the Florida Keys.

[4] Florida Department of Transportation comments, July 20, 2016 in RM-11681. https://ecfsapi.fcc.gov/file/1072020498400/ligado%20reply%20comments%20160619.docx

Florida Bridge Mounted Wind Speed Alerting System
(GOES-R Reporting via 1679-1680 MHz)[5]

The current proposal from Ligado only protects certain Federal users (only a limited number of NOAA sites) from interference (and the protection zones as currently proposed may not even do that) – but no other direct users.

<u>Projected Impacts to Ground Station Receivers</u>

Ligado referenced adjacent band testing conducted by Microcom Design[6] in their August 11, 2016 reply comments in the RM-11681 proceeding. However they apparently overlooked that this study was directed at the use of wireless handsets, not towers, in the adjacent band, and failed to mention the in-band testing performed by Microcom Design in proximity to an operational GOES earth station in the 1675-1695 MHz band. Microcom, operating with an FCC temporary authority to

[5] http://www.ops.fhwa.dot.gov/publications/fhwahop12046/rwm09_florida1.htm

[6] Letter filed by Microcom Design, Inc. on June 17, 2016 in proceeding RM-11681 https://ecfsapi.fcc.gov/file/60002346697.pdf

radiate handset level power LTE signals open air, was able to cause GOES satellite reception throughout 1675-1695 MHz to fail. If the less powerful handset level signal would impact the ground station, there is no question that the proposed Ligado towers, at 20 million times more power than the handset, could impact the hydrometeorological receiving equipment within an extremely large radius of at least 100 kilometers. The Microcom Design in-band presentation concludes that "Under no circumstances should towers be allowed to transmit in band."

The in-band band test results are attached to this Ex Parte presentation.

In addition, Mr. Betsill pointed out that his company has sold at least four receiving systems in Canada, where they would be located within 50 miles of the U.S. Canadian border. Cross-border interference would likely be a problem since the proposed Ligado towers just over the border could still be close enough to create disruptions for such stations. Receiving stations in Canada[7] for geostationary satellites would be pointed generally to the South at lower angles of elevation, which also would be in the general direction of the tower signals, increasing the potential for dangerous interference.

<u>Real-Time Weather Data Delivered via Content Delivery Networks Inadequate</u>

Dr. Gerth described the real-time mission of the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison[8], and its long standing partnership on satellites with NOAA through its Cooperative Institute for Meteorological Satellite Studies (CIMSS). Since SSEC has been involved in weather satellites from the beginning of the technology in the 1960s, with the first meteorological satellites developed by professors at the university, their organization collects and stores real-time weather satellite data.

Unlike traditional research that might occur in a chemistry laboratory, meteorological research is done right now, outside, in real-time. SSEC relies upon direct broadcast reception of NOAA satellite data to perform its mission. NOAA needs the insights from this real-time research to supplement their real-time operations. SSEC often provides guidance to NOAA centers such as the National Hurricane Center in real-time.

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[7] See the comments of the Meteorological Service of Canada, Government of Canada, dated June 21, 2016 in RM-11681
https://ecfsapi.fcc.gov/file/10621943011478/FCGEO%20Response%20to%20FCC%20RM%2011681.pdf
Multiple filings from four Provinces within Canada are also contained within the Comments of proceeding RM-11681

[8] Comments of SSEC filed June 21, 2016 in proceeding RM-11681
https://ecfsapi.fcc.gov/file/1062147369994/FCC%20response.pdf

The vast quantity of data from the GOES-R series satellites would be extremely difficult to acquire in real-time via terrestrial means. A dedicated line to carry over 31 Mbps of continuous data from a single operational GOES-R satellite would be difficult to obtain consistently (compared with the current GOES 2.11 Mbps downlink, which could be easily accommodated by the majority of home Internet lines that typically carry 4 Mbps[9]), and NOAA plans to have two such satellite streams (e.g., 62 Mbps total) in operation after the launch of GOES-S.

A new generation Japanese geostationary satellite, Himawari-8, was placed into operation over the Western Pacific in July 2015. SSEC wanted to get that data to their location in Madison, Wisconsin, but since it is outside the viewable footprint of the Japanese satellite, they had to acquire the data via terrestrial means. To route this data from Japan would require transfer within Japan to the coast, then via an undersea cable to Los Angeles, then to a hub via Denver to Chicago, which then would connect it to Madison Wisconsin. At any point along the way, power outages or cable damage due to construction could leave SSEC without access to the data. This is not acceptable for operational meteorology applications. The letter from SSEC in the RM-11681 proceeding documents outages from terrestrial systems over a stated time period.

Past Spectrum Sharing or Repurposing of Meteorological Bands

In the total band size of 40 MHz, NOAA has already given up 20 MHz of mid-band spectrum for sharing or repurposing and they only have 20 MHz of spectrum left in this band.

- 5 MHz Converted to Exclusive Commercial Use – (1670-1675 MHz) by FCC auction 46 in 2002-2003.
- 15 MHz of Shared Spectrum for the AWS-3 Service – (1695-1710 MHz) by FCC auction 97 in 2014-2015. Coordination Zones adopted for selected Federal sites

Furthermore, the GOES-R spacecraft spectrum usage was redesigned to move GOES-R out of the AWS-3 band and below 1680 MHz.

The remaining 20 MHz of spectrum from 1675-1695 MHz is nearing the bare minimum required to support the upcoming generation of geostationary weather satellites necessary to perform their crucial, lifesaving mission. Considering that there is a fifteen-fold increase in broadcast data from the new generation GOES-R satellites as compared to the GOES satellites currently operating, accommodating high-power tower transmitters in the same spectrum creates a significant risk to the flow of hydrometeorological data.

[9]"State of the Internet", http://www.Akamai.com

Summary

Satellite data and imagery provide time-critical information about extreme events. This information improves forecasts and warnings for tornados, hurricanes, thunderstorms, floods, and solar storms. Furthermore, satellite transmission ensures that weather and water information is available quickly, reliably, and in remote locations where emergency managers, service providers, and key practitioners are often located. Consistent, reliable, and timely access to weather information is also critical to the research community and the private sector, which use the information for scientific advancement and a wide range of commercial applications.

Multiple sectors of the economy, including land, sea and air transportation and energy generation and production, require reliable real-time information to make immediate decisions to mitigate the risk of economic losses from major weather hazards and, most importantly, to ensure safety.

The internet-enabled Content Delivery Network (CDN) proposed by Ligado is not acceptable as currently proposed since it does not guarantee that all current users of this information (both Federal and non-Federal) will have uninterrupted access to this real-time information regardless of access to power and internet.

The idea that CDN distribution is a reliable solution is dangerous in the worst of times. For example:

- Tornados such as the one that occurred in Joplin, Missouri in 2011, killed more than 150 people, injuring more than 1000 others, and caused damages amounting to a total of $2.8 billion, and
- Floods currently underway in North Carolina, where to date, 20 people have been killed and thousands have been displaced.

Spectrum sharing may be an important mechanism for bringing in multiple compatible uses to a segment of the radio spectrum. However, the towers proposed by Ligado Networks are about 20 million times stronger than the data originating from a wireless handset. It has been shown that wireless handsets can interfere with meteorological satellite earth stations can cause interference in adjacent bands and will most likely cause if they transmit in the same frequency spectrum. Therefore, placing towers with the higher signal levels, in-band, could create issues for receivers placed at vast distances. If those towers are allowed in or near the same frequency band as the earth stations, it is the opinion of radio frequency engineers that all of the major downlinks in 1675-1695 MHz (e.g., GOES-R DCS, GOES Rebroadcast, and HRIT/EMWIN) will be adversely affected.

Sensitive earth stations receiving satellite data simply cannot properly function in the presence of strong terrestrial signals that share the same radio spectrum. The mitigations that are available to reduce the effects of interference from adjacent band signals do not work with extremely strong sources in the same band.

Solutions proposed for meeting or restoring this direct broadcast capability through surface-based approaches (e.g., cloud computing services) have, thus far, been inadequate because they do not appear to be capable of providing data and information as quickly, reliably, and for the full range of potential users as the current spectrum-based approach.

As a result, sharing the 1675-1680 MHz radio spectrum poses significant risks to the nation's forecast, communication, and warning capabilities for extreme events. The potential degradation in this capability would create risks to public health and safety, private sector initiatives, and scientific advancement. Before any further efforts are made toward a notice of proposed rulemaking in this matter, additional research that is both independent and comprehensive is required.

Submitted by the briefing participants from the hydrometeorological and ground system equipment manufacturing communities.

DCS & LRIT LTE In-Band Interference Study

Microcom Design, Inc.

April 2016

Study Goal

- Determine the susceptibility of DCS and LRIT reception to interference from in-band LTE transmitters
  - The study focused on hand held transmitters because of the power limitations of the signal generator

Setup

- **Transmit**
  - Agilent N5182B signal generator
  - ¼ wavelength dipole antenna
  - 5 MHz wide band with 100% utilization
  - Center frequency of band was set to 1693 MHz to impact both DSC and LRIT simultaneously
  - Power adjusted from -23 dBm to +20 dBm in 1 dBm steps

- **Location**
  - One transmission location was used
  - Site was chosen because it provided a consistent line of site to the front of the antenna while being 250 feet away

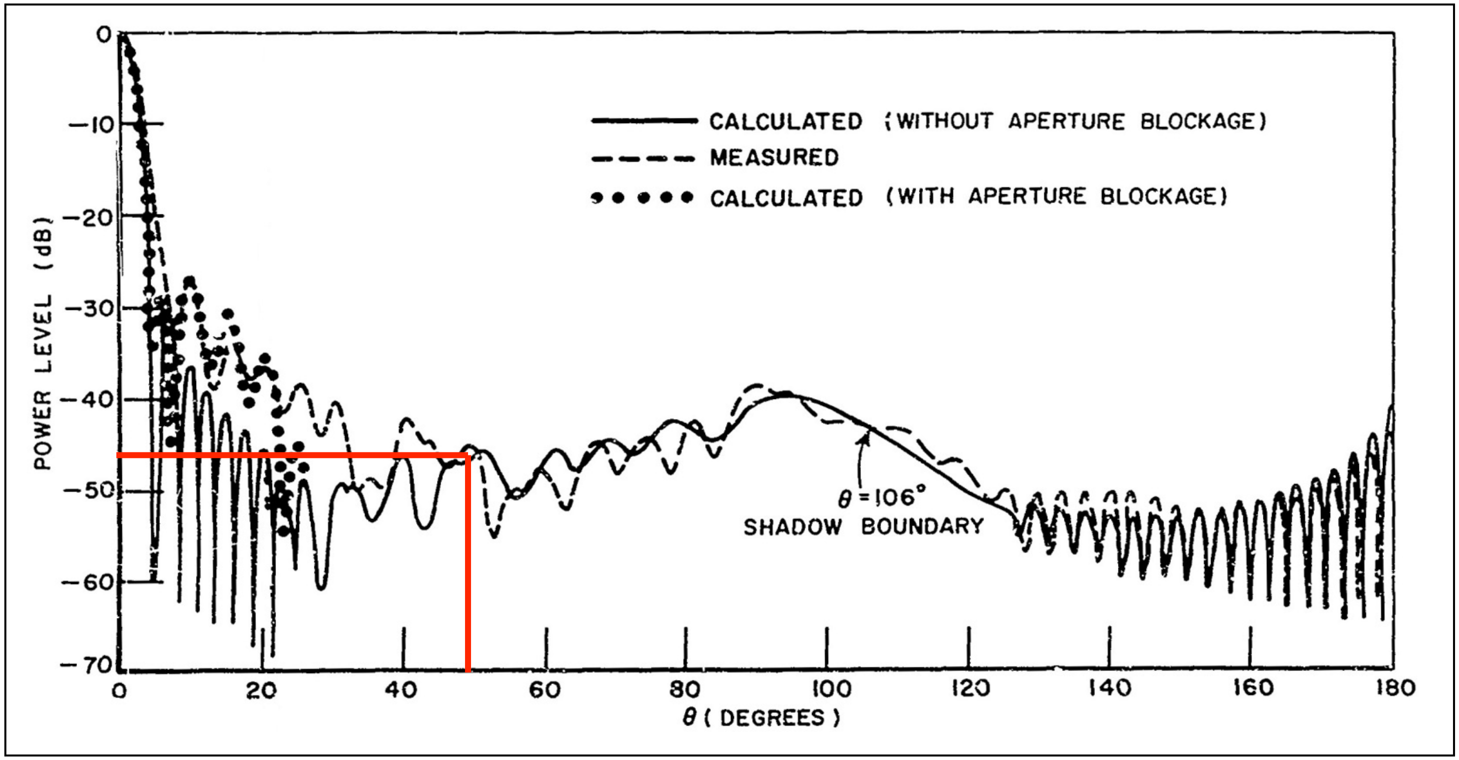
Setup

- **Receive**
  - **DCS 3.6 meter dish**
  - **LRIT 1.2 meter dish**
  - **Limited study to GOES East reception / Interference**

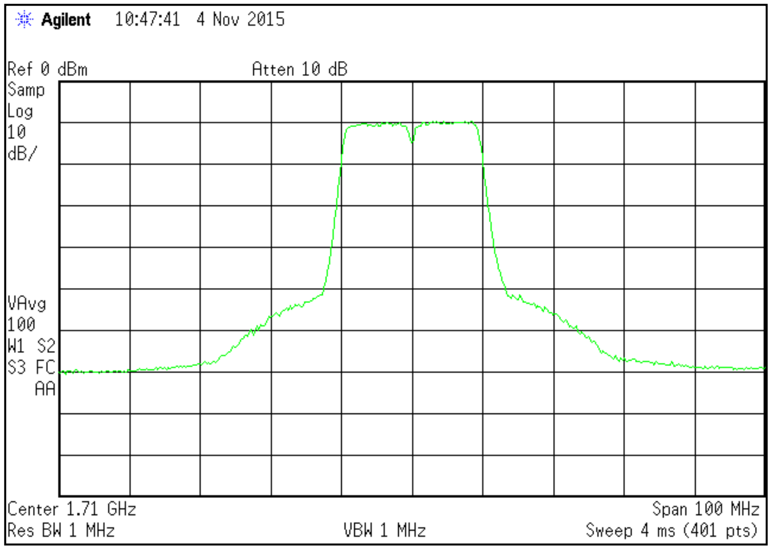
- **Link**
  - **250 foot separation between transmitter and receive dishes**
  - **DCS and LRIT dishes pointed 49° off axis from LTE transmitter**

Antenna

- **Estimated Location within example parabolic dish gain pattern**
  - **Transmitter located 49° off center, about -47 dB down**



Example Interference Waveform

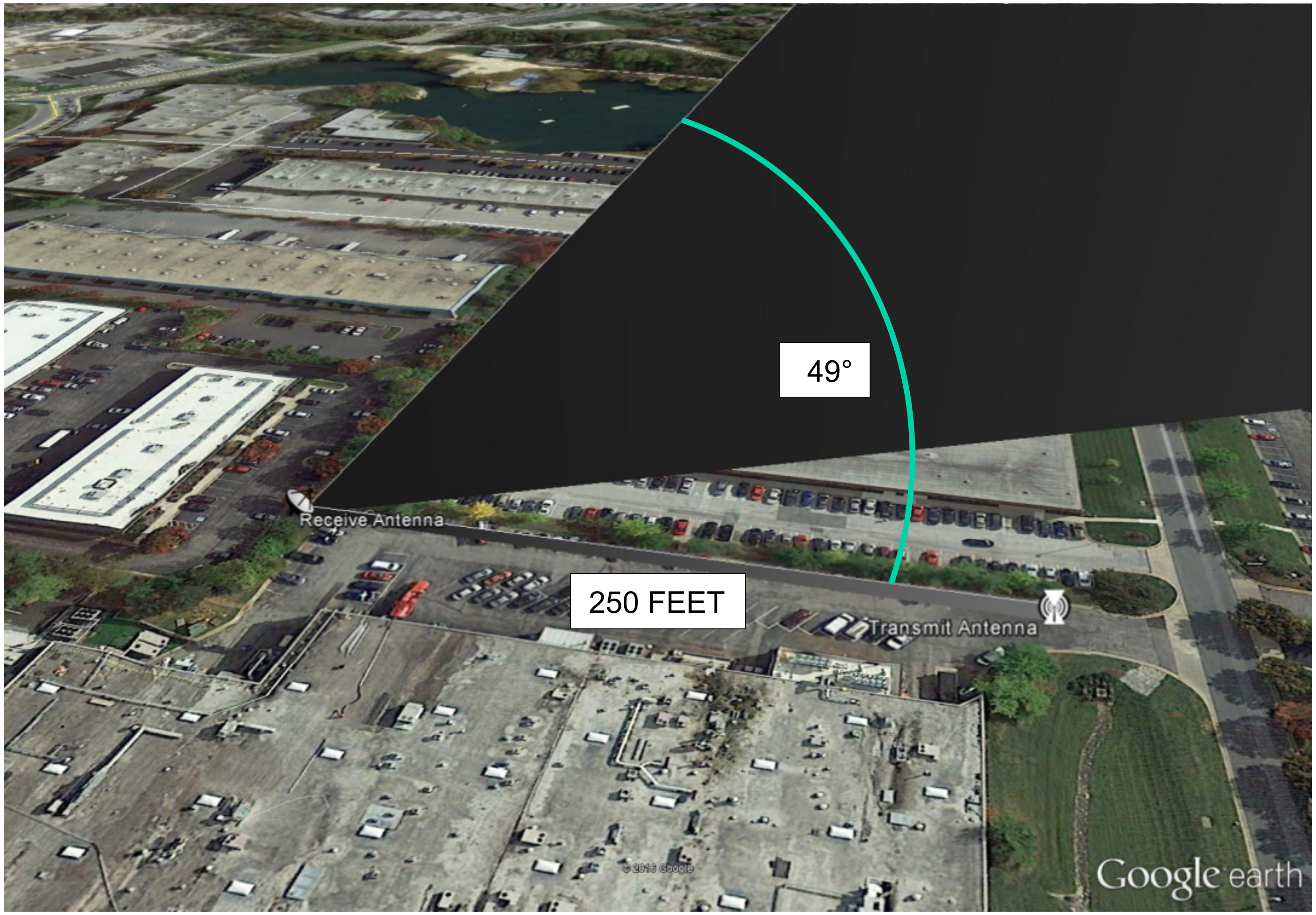


- Example LTE signal from signal generator demonstrating ability meet the LTE requirement of -25 dB down within 10 MHz and -47 dB down outside 10 MHz
- LTE bandwidth is adjustable between 6 options (1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, 20MHz). The above picture shows the 10MHz option

Data Source

- DPCM phase noise measurements were recorded from the Microcom Design DAMS-NT Client software DPCM Pilot Level / Noise Floor Graph
- LRIT Reed-Solomon success percentages were recorded from the Microcom Design DAMS-NT DigiRIT DIGITAL LRIT/ HRIT RECEIVER front panel display
- 70 MHz tap from the DCS antenna front end was fed into an Agilent E4402B spectrum analyzer
- Screen shots were taken from the spectrum analyzer

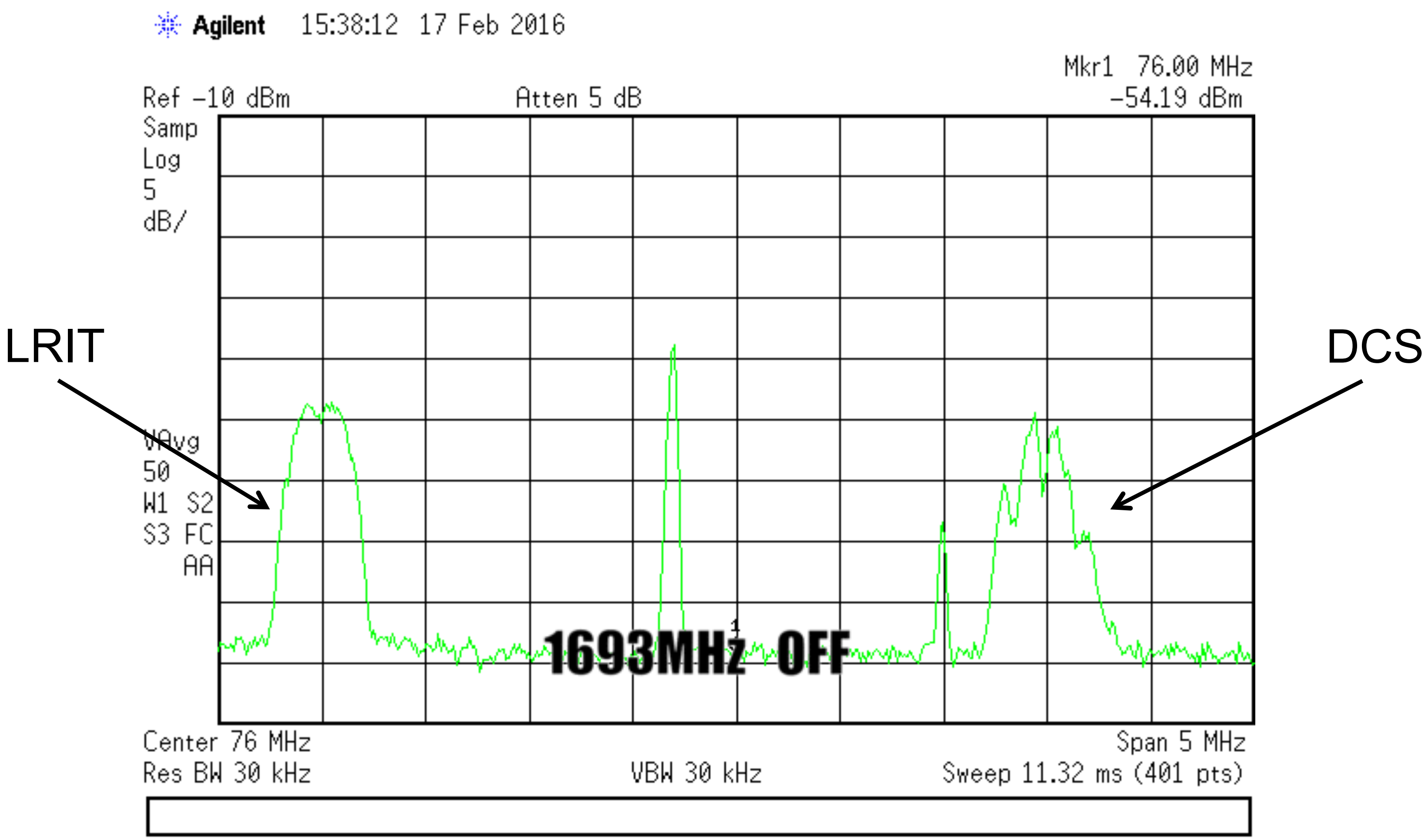
Site Arial View



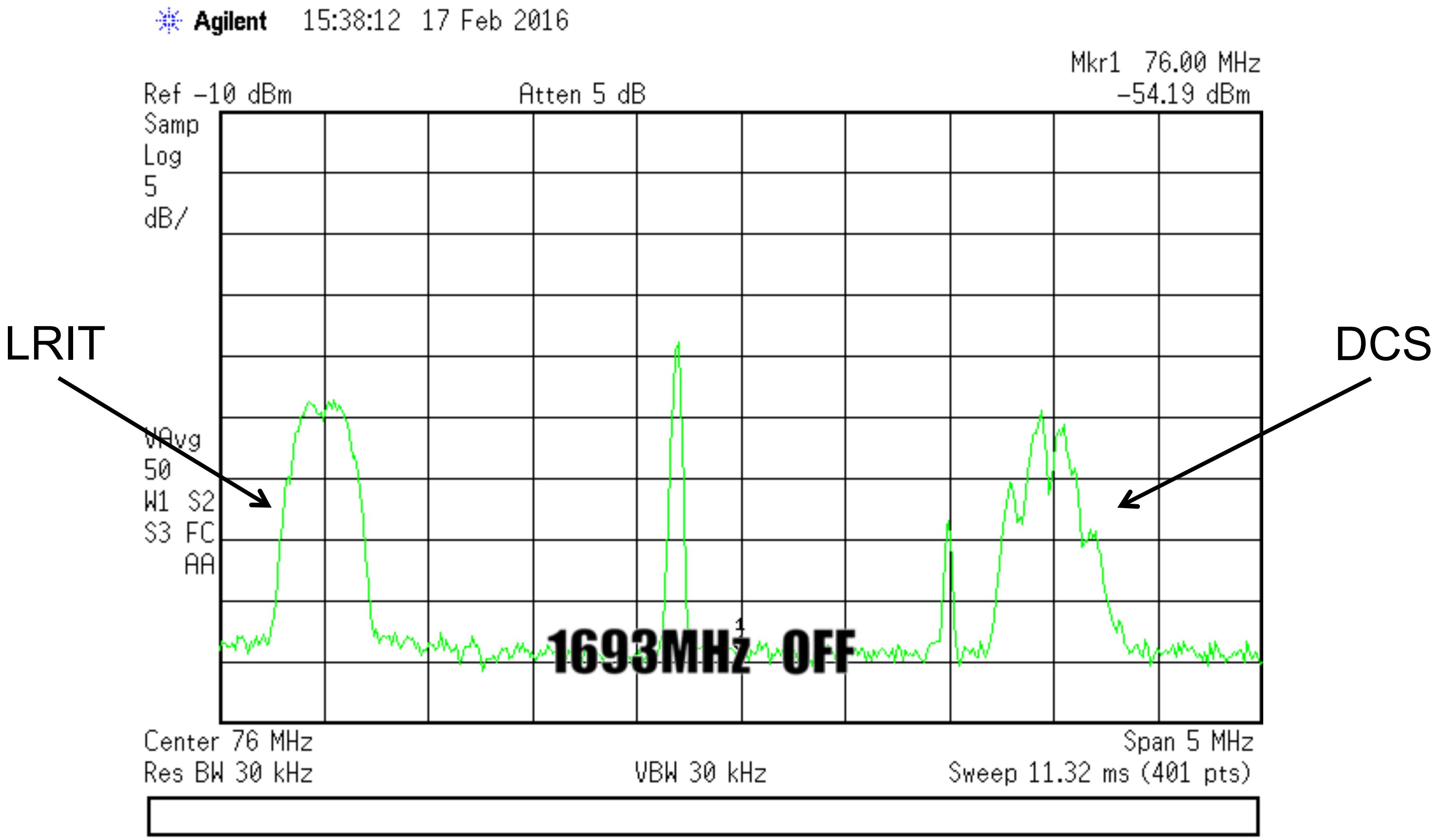
Testing Results

- Transmit power at : -11 dBm
  - LRIT Reed Solomon Success percentage dropped to 98
- Transmit power at : -8 dBm
  - LRIT lost frame sync
- Transmit power at : +1 dBm
  - DRGS phase noise rose from 2.2 ° to 3.0 °
- Transmit power at : +19 dBm
  - DRGS lost carrier lock

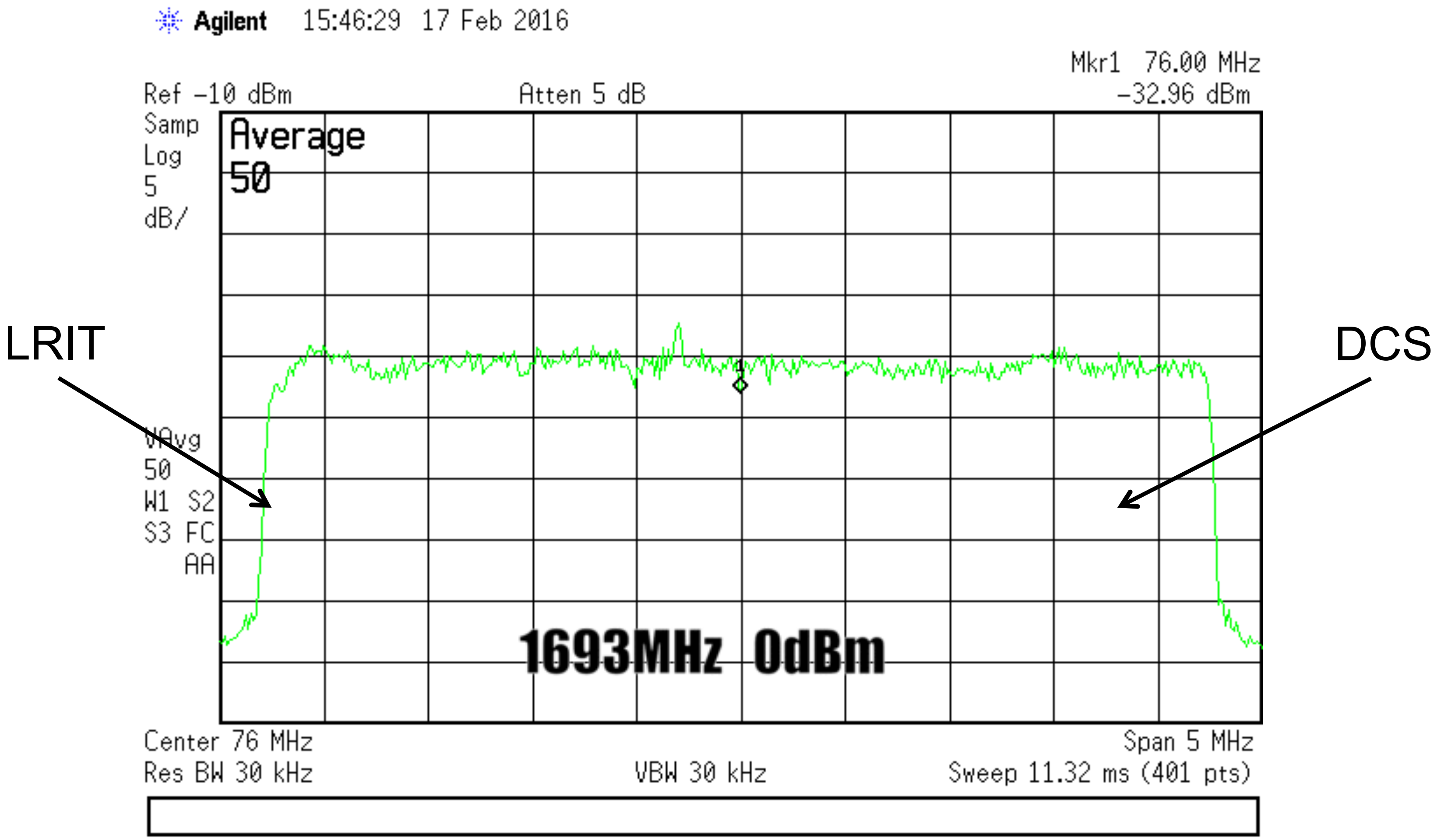
LTE In Band Interference Animation



LTE In Band Interference Animation



LTE In Band Interference Animation



Cause of interference

- LTE signal swamped DCS and LRIT signals
- The LRIT receiver was more susceptible then the DCS most likely due to the smaller 1.2 meter dish vs the 3.6 meter DCS dish
- The 1.2 meter LRIT dish has a lower gain and lower SNR then the 3.6 meter DCS dish
- The interfering signal was coupling in significant energy even though the radiating element was far off in a side lobe

Summary

- Receive sites are highly susceptible to in band interference
  - Testing showed that complete data loss can be caused by an LTE handset transmitting near a receive site antenna even with relatively low transmit power

- Handset transmitting 250 feet away from and 49° off axis from receive dish can cause interference with as little as -11 dBm of power

Recommendation

- All efforts should be made to not allow band sharing
- If band sharing is allowed then a large quiet zone around receive antenna must be created
- Under no circumstances should towers be allowed to transmit in band